ISS PRA:

Modeling Payload Stowage Impacts to Fire Risks On-board the International Space Station

April 8, 2010

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Purpose/Background

- ***Purpose*: To determine the risks of fire on-board the ISS due to non-standard stowage**
- ***Background*:**
  - *ISS stowage is constantly being re-examined for optimality*
  - *Non-standard stowage involves stowing items outside of rack drawers*
  - *Fire risk is a key concern and is heavily mitigated*
  - *Methodology needed to account for fire risk due to non-standard stowage to capture the risk*

ISS022E015936

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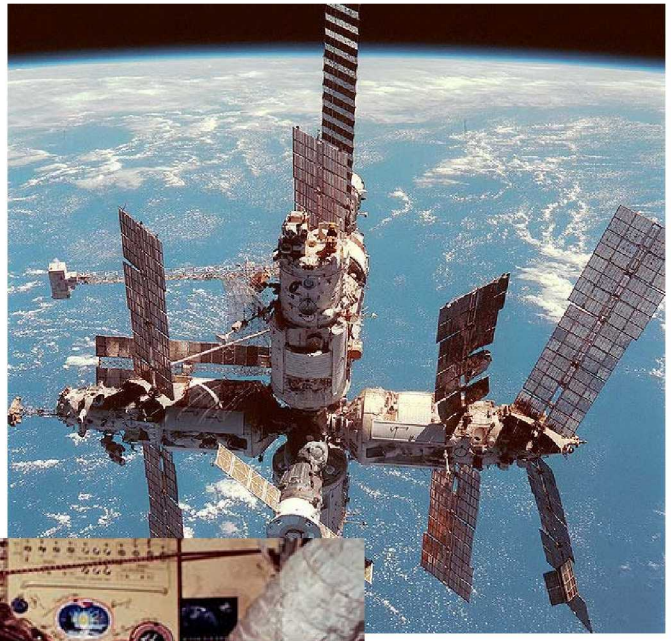
Fire Risk Background

- ***Why is fire a concern on-board ISS?***
  - *Experience: Mir*
  - *Crew safety*
    - » *Air quality*
    - » *Injury*
    - » *Death*
  - *Lead to other failures*



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General *Assumptions*

- **Materials**
  - Material selection
    - » Control combustibility
    - » Control fire propagation
    - » Minimize fire risk
  - Propagation is mitigated in material selection
    - » Tests for propagation to determine suitability
- **Human factors**
  - Processes are in place to minimize fire risk
    - » Minimum distances between payloads and ignition sources
    - » Personal effects stowage
  - Dependent on human adherence to the process
- **Microgravity**
  - Fire behaves differently
    - » Hotter
    - » Shape and movement
    - » Oxygen sourcing

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Modeling Techniques

- **Qualitative**
  - Payloads
    - » Volume layouts
    - » Flammability factors
  - Co-location
    - » Human Error Probabilities (HEP)
    - » Proximity likelihood
  - Fire
    - » Modeling
    - » Expert elicitation

ISS022E043794

- **Quantitative**
  - Basic events probabilities derived from qualitative analysis
    - » Factor indices
  - SAPHIRE event tree and fault tree structure

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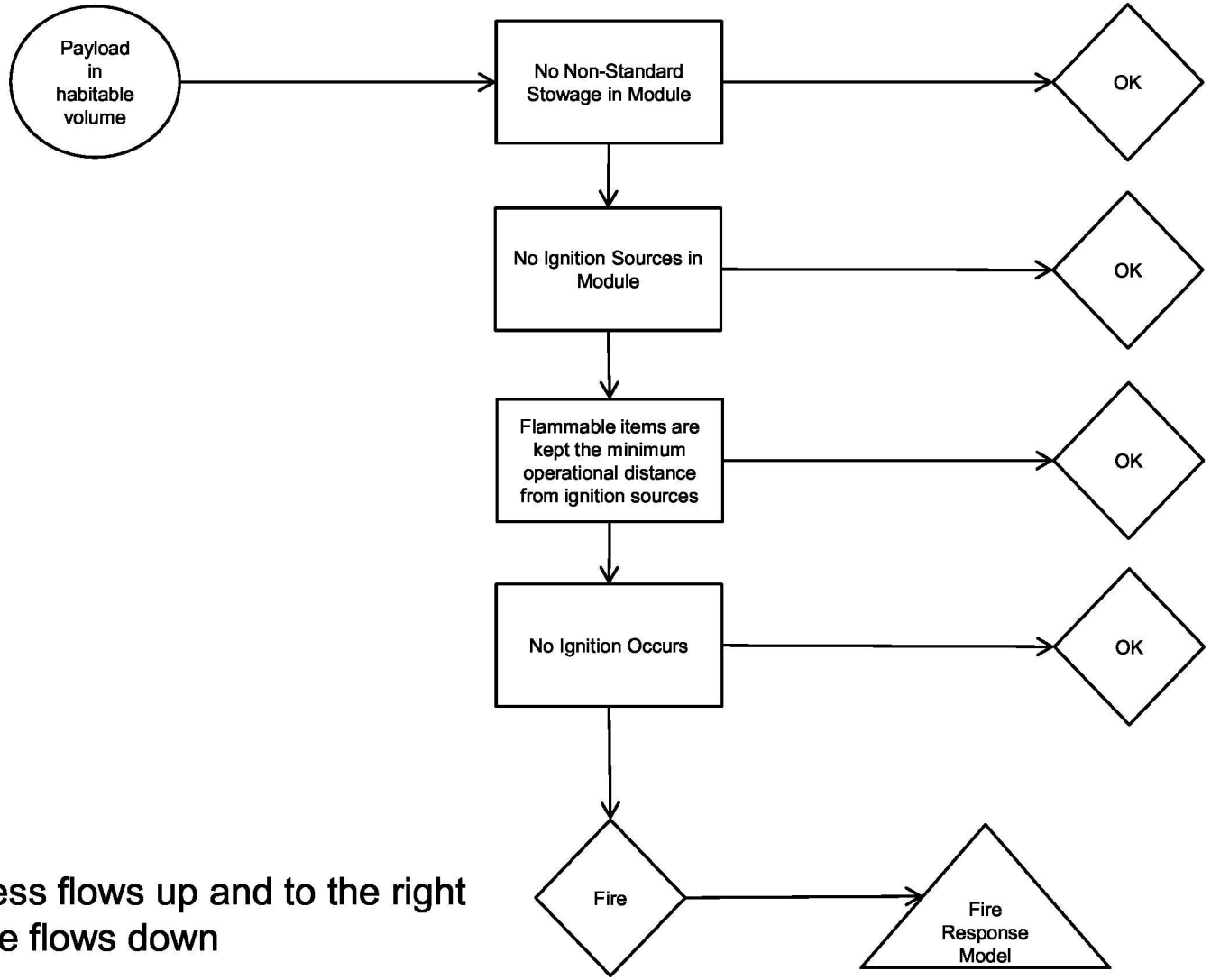
Event Sequence Diagram (ESD):



Success flows up and to the right
Failure flows down

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Qualitative Fire Analysis

Module	Quantity	% Utilization (1-5)	Age (1-5)	PCU Factor
	1	0.8	0.2	Calc
AIRLOCK	1	2	3	3
ATV				0
COLUMBUS	3	4	3	12
DC1				0
FGB	3	2	3	7
HTV				0
JEM	2	5	1	9
JLP				0
NODE 1	3	2	3	7
NODE 2	1	5	3	5
NODE 3	2	4	1	7
PGS				0
SM	4	5	4	20
SYZ				0
US LAB 15A	9	3	3	27
US LAB 20A	9	3	3	27

- Use counts, utilization, age

Define factors

- Weighted products of parameters

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Qualitative Fire Analysis

COMPONENT	Likely Hood Factor (1-5)	ATV	COLUMBUS	JEM	JLP	NODE 1	NODE 2	NODE 3	US LAB 15A	US LAB 20A
PSU_SSC	4	0	32	20	0	36	20	56	96	120
Display & Monitor	3	0	0	0	0	0	0	3	39	27
Printer	2	0	0	0	0	0	0	0	6	6
Exercise Equip	3	0	0	0	0	0	0	12	9	9
Battery	4	16	0	0	0	0	0	0	8	8
O2 Supply Tank	2	4	0	0	0	0	0	0	0	0
Galley	5	0	0	0	0	0	0	0	5	5
Payload (Misc. Equip.)	3	0	78	102	0	0	3	69	147	117
Compressor	4	0	0	0	0	0	0	0	0	0
Electrial Heater	5	0	0	0	0	0	0	0	0	0
Pump Assembly	1	0	5	8	0	0	8	8	5	5
Fans	2	0	34	34	0	46	20	68	46	46
Hydrogen	2	0	0	0	0	0	0	6	2	0
		81	499	695	20	366	456	875	1936	1902
	15A	1%	7%	9%	0%	5%	6%		26%	
	20A	1%	6%	8%	0%	4%	6%	11%		23%
	15A	1%	7%	9%	0%	5%	6%	0%	26%	0%
	20A	1%	6%	8%	0%	4%	6%	11%	0%	23%

- Develop indices
  - % of overall fire risk
- Convert to quantitative factor
  - Ignition source index

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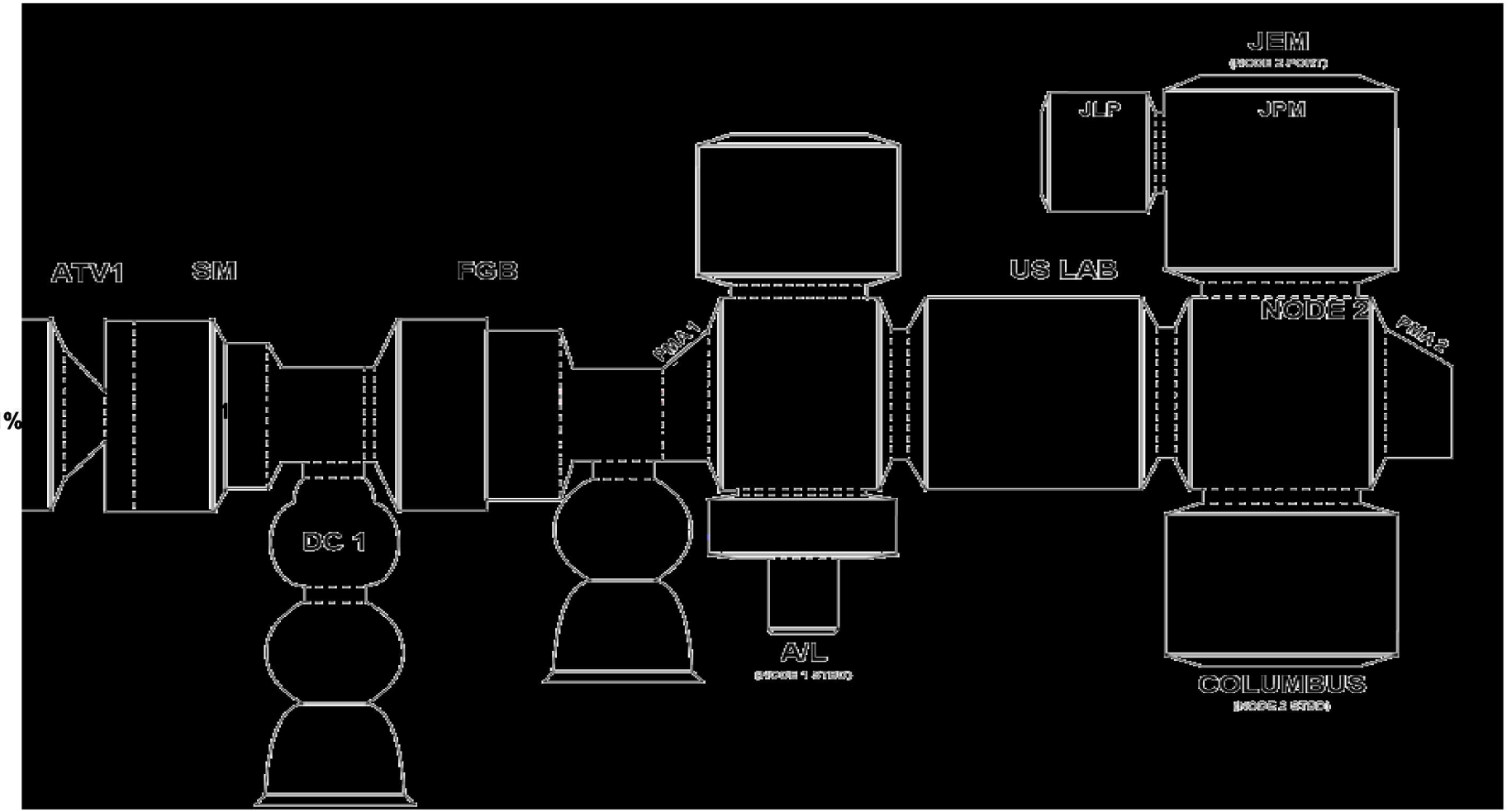
SAMPLE Qualitative Results for Fire Risk



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Qualitative Stowage Analysis

Module	Stowage Density (Vol stow/habit vol)	Density factor (0-10)	Combustibility (0-5)	Stowage Factor
		Calc		Calc
AIRLOCK	0.40	8	1	0.16
ATV	0.80	10	3	0.6
COLUMBUS	0.20	4	1	0.08
DC1	0.10	2	1	0.04
FGB	0.25	5	2	0.2
HTV	0.80	10	1	0.2
JEM	0.45	9	2	0.36
JLP	0.30	6	1	0.12
NODE 1	0.10	2	1	0.04
NODE 2	0.20	4	1	0.08
NODE 3	0.20	4	1	0.08
PGS	0.70	10	3	0.6
SM	0.50	10	2	0.4
SYZ	0.10	2	1	0.04
US LAB 20A	0.15	3	2	0.12

Calculating the Stowage Factor

- Volume
  - Habitable volume
  - Stowage CTBEs
  - Table of high to low
- Combustibility
  - Level of flammability
  - Table of high to low
- Define factors
- Develop index value
- Quantitative factor

Co-location factor to account for:

- Processes for minimum distance
- Human Error
  - CREAM or THERP analysis

Ignition factor to account for:

- Likelihood that fuel and ignition source will start fire
- Expert elicitation or fire modeling

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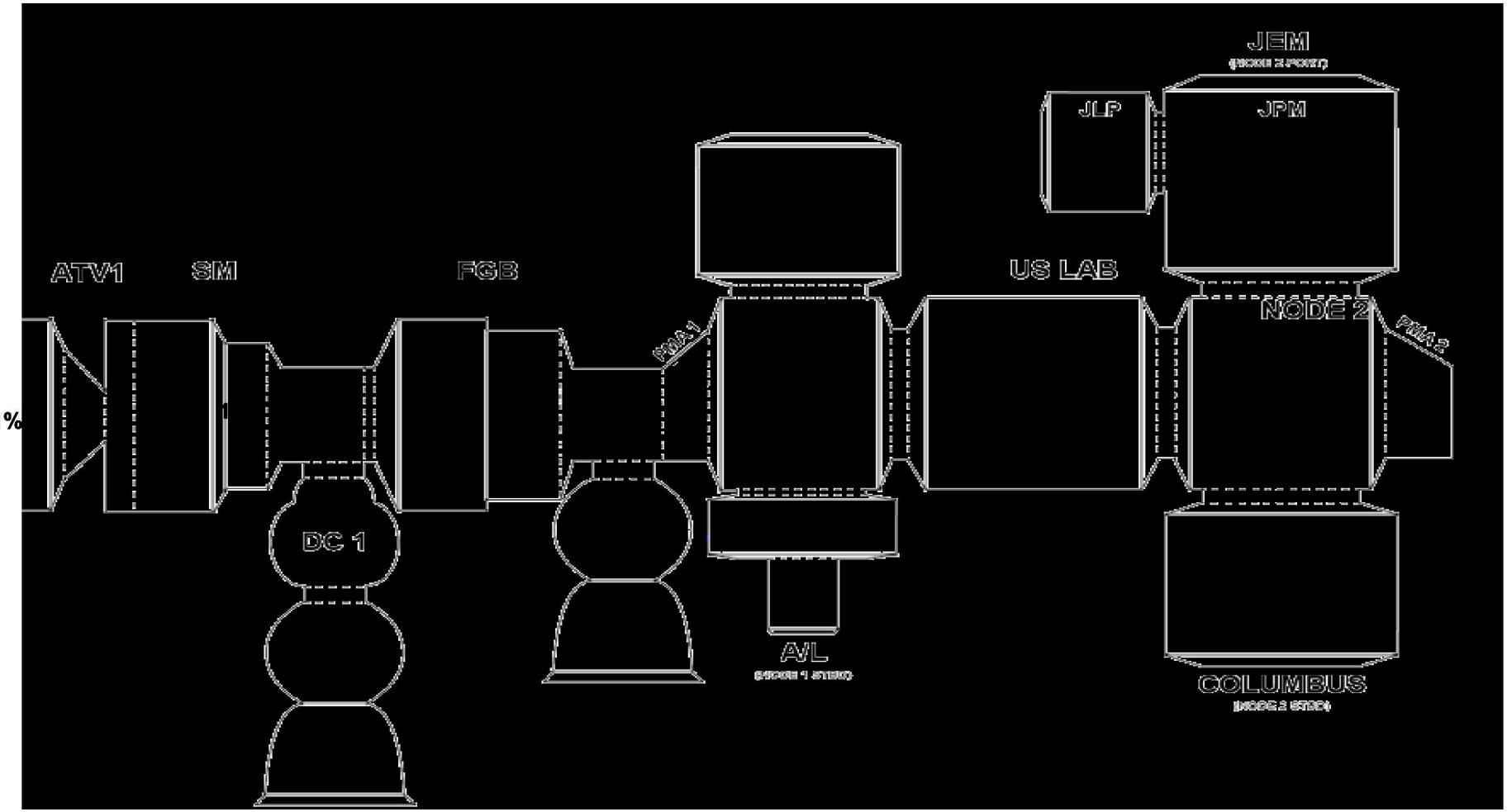
SAMPLE Qualitative Results for Non-Standard Stowage



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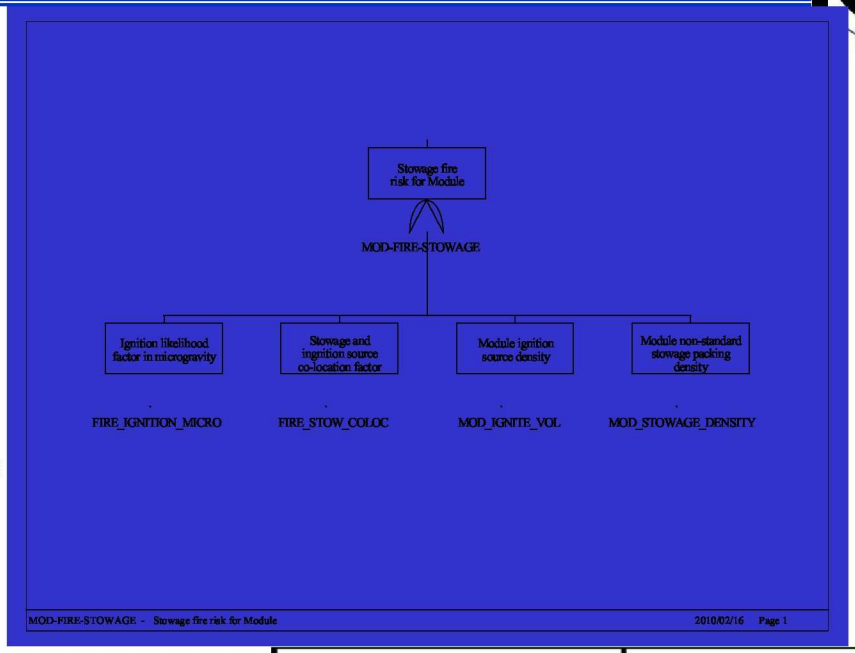
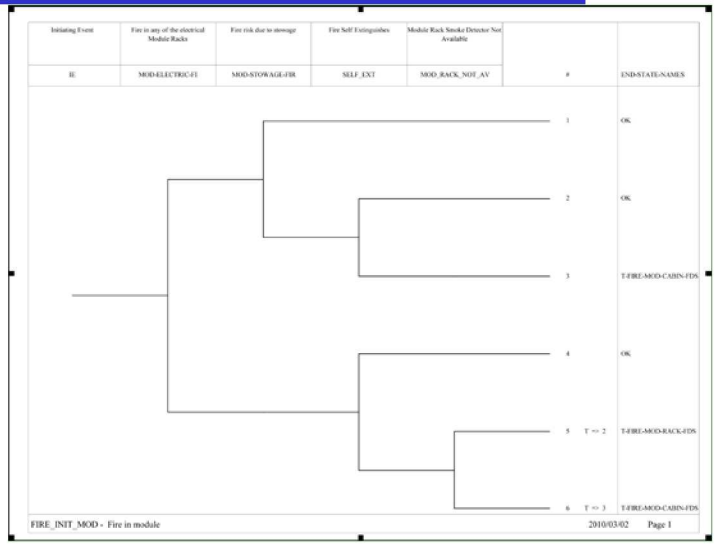
Quantitative Analysis
Basic Event Data

- ***Ignition Likelihood***
  - *Microgravity sensitive*
  - *Expert elicitation*
- ***Co-location***
  - *Human error*
  - *Items are not placed according to established processes*
- ***Ignition Source***
  - *Analysis of potential sources*
- ***Stowage***
  - *Analysis of non-standard stowage*





All conditions have to come together simultaneously to have a fire.

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Conclusions

- ***Attempt to capture fire risk on-board station***
- ***Placement of stowage and selection of materials is well mitigated***
  - *Mitigations in place*
  - *Materials testing*
  - *Human inclusion creates uncertainty*
    - » *Follow processes*
    - » *Personal effects*
- ***New methodology***
    - » *Utilizes qualitative analysis*
    - » *Develop the quantitative factors from qualitative results and elicitation*

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Conclusions

- ***Improve the fidelity of the current ISS PRA Fire Model***
  - *Accounting of factors not currently modeled*
  - *Converge towards true fire risk*
- ***Heavily mitigated***
  - *Materials and processes are designed to eliminate fire risk*
  - *Risk still remains*
  - *Personal effects add uncertainty*
  - *Human behavior is a contributor*
  - *Overall, risk likely to be low*

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